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ScienceDirect
Procedia Engineering 120 (2015) 807 – 810
Procedia Engineering
www.elsevier.com/locate/procedia

EUROSENSORS 2015

NIR micro beam-splitter by saw-dicing of glass substrate for Optical Coherence Tomography

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Abstract

This paper reports the fabrication of a near infrared (NIR) micro beam-splitter (MBS) for Optical Coherence Tomography (OCT) applications. The proposed configuration is based on saw-dicing micromachining of glass substrate combined with thin film deposition of a dielectric multilayer. In order to obtain a splitting with horizontal and vertical transmitted/reflected beams, a 45º surface was fabricated with conventional dicing blades. A dielectric multilayer based only in four thin films was optimized for NIR range (800-900 nm) and for a 50/50 non-polarized split ratio. This multilayer is deposited in the 45º micro machined surface. The MBS offers the possibility of wafer-level alignment and assembly, representing the first step towards OCT miniaturization.

Peer-review under responsibility of the organizing committee of EUROSENSORS 2015

Keywords: Near infrared; micro beam-splitter; Optical Coherence Tomography; saw-dicing; thin film

1. Introduction

Optical Coherence Tomography (OCT) is a high resolution optical imaging technology widely used in an increasing number of biomedical applications, since it provides a non-invasive and sub-micrometer diagnosis method [1, 2]. State-of-art of this technique includes different bulky and expensive systems, which operate in Fourier domain by using a broadband source and a spectrometer, known as spectral-domain OCT (SD-OCT), or by using a tunable laser, known as swept-source OCT (SS-OCT) [3]. OCT miniaturization is a real challenge for scientific

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Peer-review under responsibility of the organizing committee of EUROSENSORS 2015
doi:10.1016/j.proeng.2015.08.661

research in order to obtain a compact and portable system based on low cost fabrication technology [4–6]. The beam-splitter is a central component used for optical signal processing in the different OCT systems. Conventional cube-typed splitting, with horizontal and vertical transmitted/reflected beams, is preferable for optical alignment in integrated imaging microsystems. Depending on the application, polarization or non-polarization sensitive beam-splitters can be required [7]. In this paper, a fabrication method of a 50/50 non-polarized micro beam-splitter (MBS) is presented for near infrared (NIR) region. Based on a previous work for visible range [7] the proposed MBS is fabricated by 45º saw-dicing of glass substrate, using conventional dicing blades. Fig. 1 represents the proposed configuration for OCT applications, including metallic layers for beam waveguide in a typical Michelson interferometer.

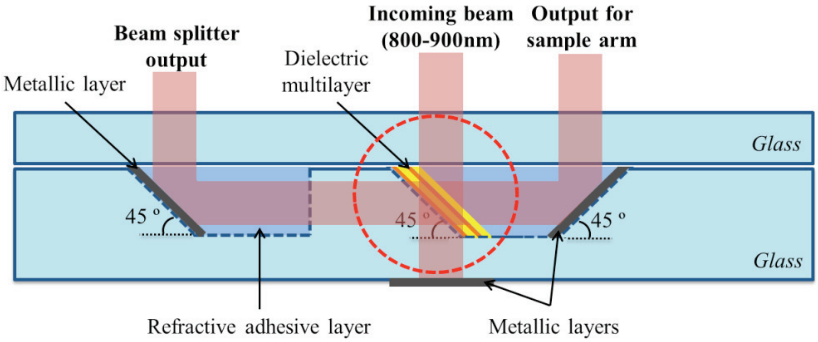

Fig. 1. The proposed MBS for NIR range, in saw-diced glass plus a dielectric multilayer for 50/50 split ratio and metallic layers for beam waveguide. In order to avoid deflection of the beams, the glass waveguide will be filled with a refractive adhesive.

2. MBS design and fabrication

The fabrication of MBS is based on two steps: 45º saw-dicing of a glass substrate and thin film deposition of a dielectric multilayer. The cuts in glass substrate were carried out by a high precision Disco DAD 2H/6T dicing saw, with conventional rectangular shape blades. To achieve the 45º surface, the substrate was first inclined to the required angle, as represented in Fig. 2. The fabrication parameters were adjusted to obtain an inclined surface of 400 μm height.

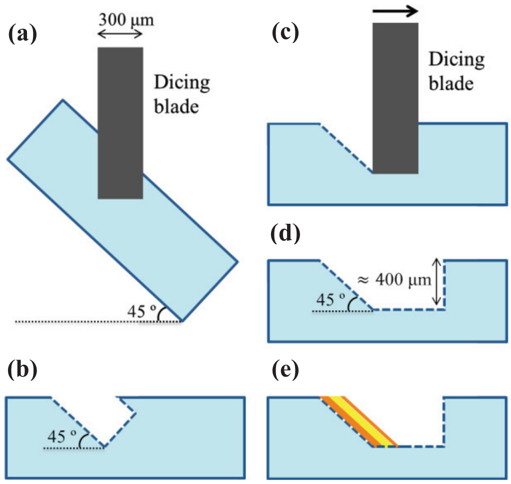

Fig. 2. Fabrication process of the MBS: (a)-(c) 45º saw-dicing of glass substrate with rectangular shape conventional blades; (d) micro structure obtained after saw-dicing; (e) thin film deposition of dielectric multilayer.

The dielectric multilayer was optimized for 800-900 nm range, using the simulation software TFCalc™. This NIR range is typically used in OCT applications for ophthalmology. After optimization of the design, a transmittance and reflectance of 50% was reached with only four thin film layers of high/low refractive index (H/L/H/L). Titanium oxide (TiO_2) and silicon dioxide (SiO_2) were the materials used with high and low refractive index, respectively. Table 1 contains the thickness of each layer after simulation. The dielectric multilayer was then integrated with optical software ZEMAX®.

Table 1. Dielectric multilayer optimized for 50/50 transmitted/reflected split ratio in 800-900 nm range, using the simulation software TFCalc™.

Layer	1 (H)	2 (L)	3 (H)	4 (L)
Material	TiO_2	SiO_2	TiO_2	SiO_2
Thickness (nm)	100	130	100	160

3. Results and discussion

Fig. 3 presents the final microstructure obtained after 45º saw-dicing of glass substrate with conventional rectangular shape blades. A 400 µm height was obtained for the inclined surface and a 44.1º angle was achieved with this fabrication method. It can be observed from Fig. 3 the high quality of the inclined surface, which is an important index to assure a thin film deposition as optimal as possible. As future work, a best surface with 45º precise inclination could be fabricated using a dicing blade with an angular shape.

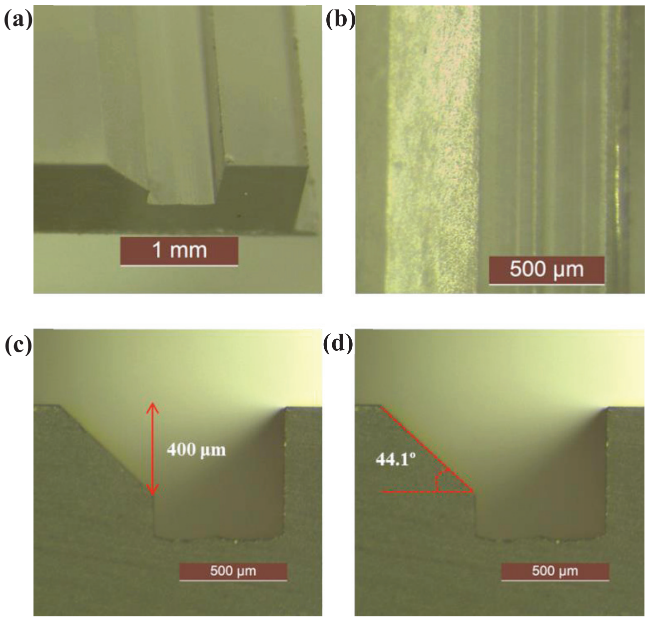

Fig. 3. (a), (b) top view and; (c), (d) cross sectional view of the inclined surface obtained with high precision Disco DAD 2H/6T dicing saw.

The ZEMAX® results (Fig. 4) show approximately a 50/50 split ratio in the required NIR range and a good performance for an incident angle of 45º. The optimization results, using a continuous target for S and P polarizations in the required range (800-900 nm), demonstrates that is possible to fabricate a 50/50 non-polarized MBS with only four layers of TiO_2/SiO_2 deposited in a 45º glass surface. This configuration allows vertical and horizontal separation between transmitted and reflected beams.

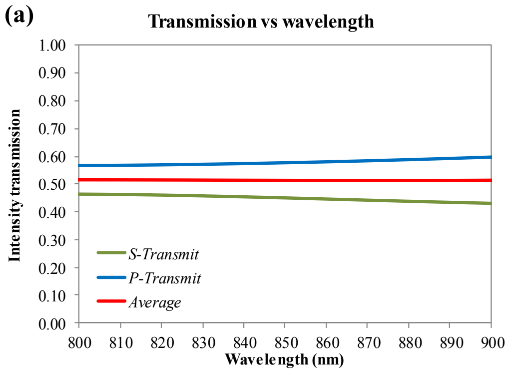

Fig. 4. (a) ZEMAX® transmission versus wavelength graphic of dielectric coating in NIR range (800-900 nm). The average intensity of transmission is 0.50; (b) ZEMAX® reflection versus incident angle graphic of the dielectric coating imported from TFCalc™. The simulation was optimized for 0.50 average reflection in 45º incident angle.

4. Conclusion

This paper reports a simple fabrication method of a MBS based on saw-dicing of glass substrate and on thin film deposition of a dielectric multilayer. The microstructure obtained by saw-dicing of glass substrate with conventional blades shows a good approximation to the 45º required angle. TFCalc™ and ZEMAX® simulations have proved that is possible to obtain a 50/50 non-polarized split ratio with only four layers. Depending on the required application, MBSs with different split ratios could be easily obtained by changing the dielectric coating. The proposed configuration allows rapid and low cost fabrication and offers the possibility of wafer-level assembly in a miniaturized OCT system.

Acknowledgements

Marino Maciel was fully supported by the Portuguese Foundation for Science and Technology under grant SFRH/BD/95706/2013.

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